Arizona Department of Water Resources

Groundwater Flow Model Scenarios of Future Groundwater and Surface Water Conditions: Sierra Vista Subwatershed of the Upper San Pedro Basin - Southeastern Arizona

By

Steven W. Corell

Hydrology Division

Supplement to Modeling Report No. 10

Phoenix, Arizona
December 1996

Arizona Department of Water Resources

Groundwater Flow Model Scenarios of Future Groundwater and Surface Water Conditions: Sierra Vista Subwatershed of the Upper San Pedro Basin - Southeastern Arizona

By

Steven W. Corell

Hydrology Division

Supplement to Modeling Report No. 10

Phoenix, Arizona
December 1996

Table of Contents

Tables

Graphs

Note: Graphs 1, 2 & 3 are located in Appendix I.

Figures

Note: Figures 2 through 16 are located in Appendix I.

USP Model Scenarios of Future Groundwater and Surface Water Conditions

Introduction

The Upper San Pedro groundwater flow model (Corell et al, ADWR 1996) was utilized to quantitatively evaluate the effects from several water management options on the groundwater system between the years 1990 and 2030. The Upper San Pedro Technical Committee discussed and developed assumptions for the simulations. ADWR added an initial baseline model run, Scenario 0, which simulated continued groundwater pumping conditions at 1990 levels, and the phasing out of agricultural pumpage in the Palominas/Hereford area by the year 2000. Scenario 1.1 simulated increases in groundwater pumpage based on population growth projections provided by the Department of Economic Security (DES) and effluent recharge at the City of Sierra Vista Wastewater Treatment Plant (SV-WWTP) and at the Fort Huachuca Wastewater Treatment Plant (FH-WWTP). Scenario 1.1 also simulated no agricultural pumpage after the year 2000. Scenario 1.2 was similar to Scenario 1.1, however agricultural pumpage in the Palominas/Hereford area remains in the model for the entire simulation. Scenario 2 simulated increases in groundwater pumpage based on reduced population projections (vs. Scenario 1.1 & 1.2) provided by DES and effluent recharge at the SV-WWTP and at the FH-WWTP. Scenario 2 simulated no agricultural pumpage after the year 2000. The final scenario model run, Scenario 3, simulated increases in groundwater pumpage based on population projections greater than Scenario 1.1 and 1.2, no effluent recharge at the SV-WWTP and FH-WWTP together with increased evapotranspiration. Scenario 3 again had no agricultural pumpage after the year 2000.

Scenario simulations began when the transient-state model ended in 1990. Four additional stress periods were added based on the population data provided by DES. All model input data

were held constant as shown in reference, with the exceptions of groundwater pumpage, effluent recharge, and increased evapotranspiration for Scenario 3. Figure 1 provides the location of the USP model, the model grid, and the location of the effluent recharge sites. The additional model stress periods were as follows.

Stress Period	Years
14	1990
15	1991-1999
16	2000-2010
17	2011-2020
18	2021-2030

Evaluating the model results of each model scenario simulation consisted of comparing the relative change in groundwater elevations versus final calibrated transient model 1990 water levels, discussing the water budget components of each model scenario, and discussing changes in simulated streamflow of the San Pedro River.

It is important to understand when evaluating the change in groundwater levels as compared to the model simulated 1990 water levels, that the relative change is what is important. The relative change is an indicator of how the model responds to a unique set of stresses on the groundwater system. The absolute change in groundwater levels simulated by the model may not be highly precise due to the margins of error or uncertainty within the model. However, absolute changes in groundwater levels were provided to illustrate the relative impacts of each of the model scenarios for comparative purposes. Graphs and figures illustrating the results from the model scenarios are provided in Appendix I. Table 1 (pg. 15) provides a summary of the USP model scenarios.

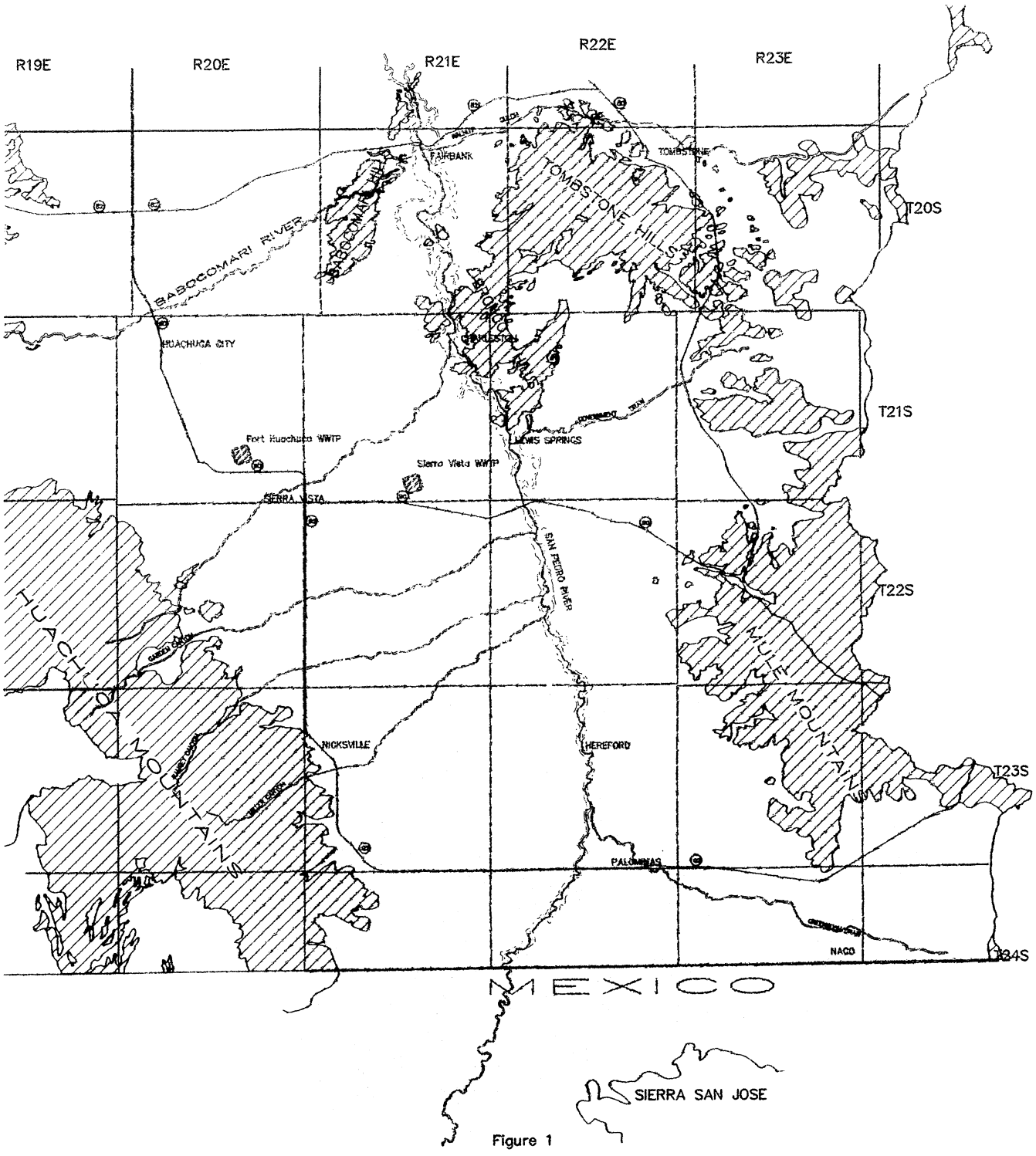


Figure 1

Upper San Pedro Model Area and Recharge Locations

HIGHWAYS
RIVERS
RIPARIAN CORRIDOR
USP MODEL GRID
HARDROCK
RECHARGE SITE LOCATION

N

2 0 2

MILES

Model Scenarios

Scenario 0--Baseline Conditions/No Effluent Recharge

An initial baseline model simulation, Scenario 0, was run using model data from the final transient-state calibrated water year (1990). Scenario 0 was run through the year 2030 using 1990 stresses (e.g. groundwater pumpage, recharge, evapotranspiration etc.). Agricultural pumpage in the Palominas/Hereford area was phased out by the year 2000. Also, Scenario 0 simulated no effluent recharge. Scenario 0 simulates no growth in the basin after 1990.

Figures 2, 3, and 4 illustrate the change in simulated groundwater levels [for: (1990 water level - 2030 water level)] compared to 1990 model simulated water levels for model layers 1, 2, and 3. The reduction of agricultural pumpage in the Palominas/Hereford area has allowed water levels to rise 5 to 10 feet in this area. Groundwater levels in the Sierra Vista/Fort Huachuca area and in the Huachuca City area continue to decline. Water levels in the Sierra Vista area decline as much as 45 feet compared to 1990 water levels. Water levels decline as much as 15 feet in the upper reaches of the Babocomari River, which is ephemeral at this time near Sierra Vista. By the year 2030 about 5 feet of drawdown has occurred along the northern half of the San Pedro River (Figure 3).

Model simulated streamflow at the Palominas gage increased from 1.13 cfs to 2.2 cfs (1990 to 2030). The increased streamflow at the Palominas gage was a result of eliminating the agricultural pumpage in the year 2000. Model simulated streamflow at the Charleston gage increased from 4.81 cfs to 5.74 cfs (1990 to 2030), again the result of eliminating agricultural pumpage. The model simulated streamflow at the Tombstone gage decreased from 8.32 cfs to 7.86 cfs (1990 to 2030). The reduction in streamflow at the Tombstone gage is likely a result of

groundwater declines near the river caused by pumping in the Huachuca City and Sierra Vista area. Figure 3 indicates the 5 foot groundwater drawdown contour has nearly intercepted the San Pedro River by 2030. Simulated streamflow on the Babocomari River declines from 1.14 cfs to 0.46 cfs (1990 to 2030) at the Canyon entrance of the Babocomari Hills.

Summarizing Scenario 0, a no-growth, no-effluent recharge scenario, groundwater depressions in the Huachuca City and Sierra Vista areas continue to deepen and expand, reaching the upper reaches of the Babocomari River and reaching the northern half of the San Pedro River. Baseflow at the Palominas gage improves as a result of the elimination of agricultural pumpage in the Palominas/Hereford area and a subsequent rise in groundwater levels in that area. Evapotranspiration increases after the year 2000 due to the rising water levels in the Palominas/Hereford area. It should be noted that the model was unable to maintain 1990 pumpage levels because model cells go dry, especially near the Huachuca mountain front. The model under simulates pumpage by approximately 8% primarily due to the decline in water levels along the Huachuca Mountains.

Scenario 1.1--Increase Groundwater Pumpage/Effluent Recharge @ Sierra Vista WWTP & Fort Huachuca WWTP

Scenario 1.1 included increases in groundwater pumpage based on population projections provided by DES. Scenario 1.1 simulates expected growth levels. The population projections were as follows:

Year	Population
1990	51,400
2000	61,140
2010	67,920
2020	73,870

Additionally, Scenario 1.1 included effluent recharge beginning in 1999 at the SV-WWTP (T21S R21E sec. 34) of 2,000 acre-feet/year, and beginning in the year 2000 at the FH-WWTP (T22S R20E secs. 22 & 23) of 944 acre-feet/year (refer to Figure 1 for the location of these recharge sites). The recharge from the SV-WWTP and FH-WWTP is simulated in the Well package of MODFLOW. Agricultural pumpage in the Palominas/Hereford area was phased out by the year 2000, and evapotranspiration was held constant at the 1990 rate.

Figures 5, 6, and 7 illustrate the change in simulated groundwater levels [for: (1990 water level - 2030 water level)] compared to 1990 model simulated water levels for model layers 1, 2, and 3. The reduction of agricultural pumpage in the Palominas/Hereford area has allowed water levels to rise 5 to 10 feet in this area. Groundwater levels in the Sierra Vista/Fort Huachuca area and in the Huachuca City area continue to decline. Water levels in the Sierra Vista area decline as much as 50 feet versus 1990 water levels. A groundwater depression is also observed in the Naco area with a 1990 to 2030 water level decline of 20 feet due to increased pumpage by Arizona Water Company-Bisbee wells. Water levels decline as much as 15 feet on the upper reaches of the Babocomari River. Figure 6 illustrates groundwater mounds that have developed at the FH-WWTP and at the SV-WWTP. The groundwater levels at the SV-WWTP rise as much as 45 feet and have allowed groundwater levels to rise along an approximately 3 mile long reach of the San Pedro River nearest the SV-WWTP.

Model simulated streamflow at the Palominas gage increased from 1.13 cfs to 2.19 cfs (1990 to 2030). The increased streamflow at the Palominas gage resulted from elimination of the agricultural pumpage in the year 2000. Model simulated streamflow at the Charleston gage increased from 4.81 cfs to 6.25 cfs (1990 to 2030), again the result of no agricultural pumpage

after the year 2000. This increase is a little higher than that observed in Scenario-0 and is probably the result of the impact of recharge at the SV-WWTP. The model simulated streamflow at the Tombstone gage increased from 8.32 cfs to 8.46 cfs (1990 to 2030). The increased streamflow at the Tombstone gage is likely a result of rising groundwater levels in the area of the SV-WWTP. Figures 5, 6, & 7 indicate that groundwater levels have declined on the upper reaches of the Babocomari River. Streamflow on the Babocomari River declines from 1.14 cfs to 0.47 cfs (1990 to 2030) at the Canyon entrance of the Babocomari Hills.

Summarizing Scenario 1.1, increased groundwater pumpage with effluent recharge, groundwater depressions in the Huachuca City and Sierra Vista areas continue to deepen and expand reaching the upper reaches of the Babocomari River and nearly reaching the San Pedro River. Groundwater declines are also observed in the Naco area near Arizona Water Company-Bisbee wells. However, the SV-WWTP recharge allows groundwater levels to rise along an approximately 3 mile long reach of the San Pedro River. Streamflow at the Palominas gage improves as a result of the elimination of agricultural pumpage in the Palominas/Hereford area and a subsequent rise in groundwater levels. Evapotranspiration increases after the year 2000 due to the rising water levels in the Palominas/Hereford area. It should be noted that the model was unable to maintain all of the increased conceptual pumpage as model cells go dry especially near the Huachuca mountain front. Approximately 10% of the pumpage was not simulated due to the water level declines primarily along the Huachuca mountain front area.

Scenario 1.2--Increase Groundwater Pumpage/Effluent Recharge @ Sierra Vista WWTP & Fort Huachuca WWTP/Include Agricultural Pumpage

Scenario 1.2 is similar to Scenario 1.1 with the exception of including agricultural pumpage in the Palominas/Hereford area for the entire model simulation. Scenario 1.2 included increases in groundwater pumpage based on population projections provided by DES. Scenario 1.2 simulates expected growth levels. The population projections were as follows:

Year	Population
1990	51,400
2000	61,140
2010	67,920
2020	73,870

Additionally, Scenario 1.2 included effluent recharge beginning in 1999 at the SV-WWTP (T21S R21E sec. 34) of 2,000 acre-feet/year, and beginning in the year 2000 at the FH-WWTP (T22S R20E secs. 22 & 23) of 944 acre-feet/year (refer to Figure 1 for the location of these recharge sites). The recharge from the SV-WWTP and FH-WWTP is simulated in the Well package of MODFLOW. Agricultural pumpage in the Palominas/Hereford area of 1,624 acre-feet/year is included for the entire model simulation, and evapotranspiration was held constant at the 1990 rate.

Figures 8, 9, and 10 illustrate the change in simulated groundwater levels [for: (1990 water level - 2030 water level)] compared to 1990 model simulated water levels for model layers 1, 2, and 3. Water levels in the Palominas/Hereford area remain about constant compared to 1990 with a small area rising about 5 feet. Groundwater levels in the Sierra Vista/Fort Huachuca area and in the Huachuca City area continue to decline. Water levels in the Sierra Vista area decline as much as 50 feet versus 1990 water levels. A groundwater depression is also observed in the Naco

area with a 1990 to 2030 water level decline of 20 feet due to increased pumpage by Arizona Water Company-Bisbee wells. Water levels decline as much as 15 feet on the upper reaches of the Babocomari River. Figure 9 illustrates groundwater mounds that have developed at the FH-WWTP and SV-WWTP. The groundwater levels at the SV-WWTP rise as much as 45 feet and have allowed groundwater levels to rise along an approximately 3 mile long reach of the San Pedro River nearest the SV-WWTP.

Model simulated streamflow at the Palominas gage increased from 1.13 cfs to 1.63 cfs (1990 to 2030). The increase in streamflow at the Palominas gage is reduced from the other model scenarios due to the additional agricultural pumpage in the Palominas/Hereford area. Model simulated streamflow at the Charleston gage decreased from 4.81 cfs to 4.74 cfs (1990 to 2030), due to additional agricultural pumpage in the Palominas/Hereford area. The model simulated streamflow at the Tombstone gage decreased from 8.32 cfs to 6.84 cfs (1990 to 2030). Graphs 1, 2, & 3 indicate that the decreased streamflow at the Tombstone gage is a result of the additional agricultural pumpage in the Palominas/Hereford area. Figures 8, 9, & 10 indicate that groundwater levels have declined on the upper reaches of the Babocomari River. Streamflow on the Babocomari River declines from 1.14 cfs to 0.47 cfs (1990 to 2030) at the Canyon entrance of the Babocomari Hills.

Summarizing Scenario 1.2, groundwater depressions in the Huachuca City and Sierra Vista areas continue to deepen and expand reaching the upper reaches of the Babocomari River and nearly reaching the San Pedro River. Groundwater declines are also observed in the Naco area near Arizona Water Company-Bisbee wells. However, the SV-WWTP recharge allows groundwater levels to rise along an approximately 3 mile long reach of the San Pedro River.

Graphs 1, 2, & 3 indicate that most of the increased streamflow observed in Scenarios 0, 1.1, and 2 is a result of the elimination of agricultural pumpage in the Palominas/Hereford area after the year 2000. It should be noted that the model was unable to maintain all of the increased conceptual pumpage as model cells go dry especially near the Huachuca mountain front. Approximately 7% of the pumpage was not simulated due to the water level declines primarily along the Huachuca mountain front area.

Scenario 2--Lower Increase in Groundwater Pumpage/Effluent Recharge @ Sierra Vista WWTP & Fort Huachuca WWTP

Scenario 2 included increases in groundwater pumpage based on decreased population growth projections (5% lower than model Scenario 1.1 & 1.2). Scenario 2 simulates a slow growth projection. The population projections for Scenario 2 were as follows:

Year	Population
1990	51,400
2000	58,600
2010	64,460
2020	68,330

Additionally, Scenario 2 included effluent recharge beginning in 1999 at the SV-WWTP of 2,000 acre-feet/year, and beginning in the year 2000 at the FH-WWTP of 944 acre-feet/year (refer to Figure 1 for the location of these recharge sites). The effluent recharge is simulated in the Well package of MODFLOW. Agricultural pumpage in the Palominas/Hereford area was phased out by the year 2000, and evapotranspiration was held constant at the 1990 rate.

Results of Scenario 2 are very similar to Scenario 1.1. This may be that the 5% pumpage

difference between Scenario 1.1 and Scenario 2 was not substantial enough to produce much variation between the two model runs. Figures 11, 12, and 13 illustrate the change in simulated groundwater levels [for: (1990 water level - 2030 water level)] compared to 1990 model simulated water levels for model layers 1, 2, and 3. The reduction of agricultural pumpage in the Palominas/Hereford area has allowed water levels to rise 5 to 10 feet in this area. Groundwater levels in the Sierra Vista/Fort Huachuca area and in the Huachuca City area continue to decline. Water levels in the Sierra Vista area decline as much as 45 feet versus 1990 water levels. Water levels decline as much as 15 feet on the upper reaches of the Babocomari River. A groundwater depression is also observed in the Naco area with a 1990 to 2030 water level decline of 20 feet. Figure 12 illustrates groundwater mounds that have developed at the FH-WWTP and SV-WWTP. The groundwater levels at the SV-WWTP rise as much as 45 feet and have allowed groundwater levels to rise along an approximately 3 mile long reach of the San Pedro River.

Model simulated streamflow at the Palominas gage increased from 1.13 cfs to 2.19 cfs (1990 to 2030). The increased streamflow at the Palominas gage resulted from elimination of the agricultural pumpage in the year 2000. Model simulated streamflow at the Charleston gage increased from 4.81 cfs to 6.25 cfs (1990 to 2030), again likely a result of no agricultural pumpage in the Palominas/Hereford area. This increase is a slightly higher than observed in Scenario-0 and is may be a result of the impact of recharge at the SV-WWTP. The model simulated streamflow at the Tombstone gage increased from 8.32 cfs to 8.4 cfs (1990 to 2030). Figures 11, 12, & 13 indicate that groundwater levels have declined on the upper reaches of the Babocomari River. Streamflow on the Babocomari River declines from 1.14 cfs to 0.47 cfs (1990 to 2030) at the Canyon entrance of the Babocomari Hills.

Summarizing Scenario 2, groundwater depressions in the Huachuca City and Sierra Vista areas continue to expand reaching the upper reaches of the Babocomari River and nearly reaching the San Pedro River. However, the SV-WWTP allows groundwater levels to rise along an approximately 3 mile long reach of the San Pedro River. A groundwater depression is also observed in the Naco area due to increased pumpage at Arizona Water Company-Bisbee wells. Streamflow at the Palominas gage improves as a result of eliminating agricultural pumpage in the Palominas/Hereford area and a subsequent rise in groundwater levels. Evapotranspiration increases after the year 2000 due to the rising water levels in the Palominas/Hereford area. It should be noted that the model was unable to maintain all of the increased conceptual pumpage as model cells go dry, especially near the Huachuca Mountain front. Approximately 8% of the pumpage is lost due to the declining water levels, primarily along the Huachuca mountains.

Scenario 3--Higher Increase in Groundwater Pumpage/No Effluent Recharge/Increased Evapotranspiration

Scenario 3 included increases in groundwater pumpage based on increased population growth projections 5% greater than those in Scenario 1.1 and 1.2. Scenario 3 is a high growth, high evapotranspiration projection run. The population projections for Scenario 3 were as follows:

Year	Population
1990	51,400
2000	64,254
2010	71,967
2020	77,724

Scenario 3 simulated no effluent recharge at the SV-WWTP and FH-WWTP (worst case scenario). Agricultural pumpage in the Palominas/Hereford area was again phased out by the year 2000, and evapotranspiration was increased to approximately 10,000 acre-feet/year. This was accomplished by increasing the evapotranspiration rate array multipliers in the MODFLOW Evapotranspiration package.

Figures 14, 15, and 16 illustrate the change in simulated groundwater levels [for: (1990 water level - 2030 water level)] compared to 1990 model simulated water levels for model layers 1, 2, and 3. The reduction of agricultural pumpage in the Palominas/Hereford area has allowed water levels to rise 5 to 10 feet in this area, similar to Scenarios 0, 1.1, & 2. Groundwater levels in the Sierra Vista/Fort Huachuca area and in the Huachuca City area decline more than in previous model scenarios. A groundwater depression is also observed in the Naco area due to increased pumpage of Arizona Water Company-Bisbee wells (30 ft. decline; 1990 to 2030). Water levels in the Sierra Vista area decline as much as 90 feet (versus 45 feet for Scenarios 0 & 2, 50 feet for Scenario 1.1) compared to 1990 water levels. Water levels decline as much as 20 feet on the upper reaches of the Babocomari River and as much as 5 feet along some portions of the San Pedro River. Streamflow of the Babocomari River declines from 1.14 cfs to 0.35 cfs (1990 to 2030) at the Canyon entrance of the Babocomari Hills.

Model simulated streamflow at the Palominas gage increased from 1.13 cfs to 1.81 cfs (1990 to 2030), a smaller increase than previous model scenarios due to increases in evapotranspiration. Model simulated streamflow at the Charleston gage decreased from 4.81 cfs to 4.56 cfs (1990 to 2030), due to declining groundwater levels and increased evapotranspiration. The model simulated streamflow at the Tombstone gage decreased from 8.32 cfs to 6.4 cfs (1990

to 2030). The decreased streamflow at the Tombstone gage is a result of declining groundwater levels in the entire NW model-area (Figure 16), and increases in evapotranspiration. The decreased streamflow for Palominas, Charleston, and Tombstone gages in stress period 15 (2000) is due to increase in evapotranspiration in stress period 15 (refer to Graph 1, 2, and 3).

Summarizing Scenario 3, allows the groundwater depressions in the Huachuca City and Sierra Vista areas to continue to expand and deepen more rapidly than in other model scenarios. Groundwater level declines are also observed in the Naco area due to increases in pumpage of Arizona Water Company-Bisbee wells. Streamflow at the Palominas gage improves only slightly after elimination of agricultural pumpage due to increased evapotranspiration It should be noted that the model was unable to maintain all of the increased conceptual pumpage as model cells go dry especially near the Huachuca mountain front. Approximately 5% of the pumpage was not simulated due to declining water levels primarily along the Huachuca mountain front area. Table 1 summarizes the results of all of the USP model scenarios.

Table 1. Summary of USP Model Scenarios

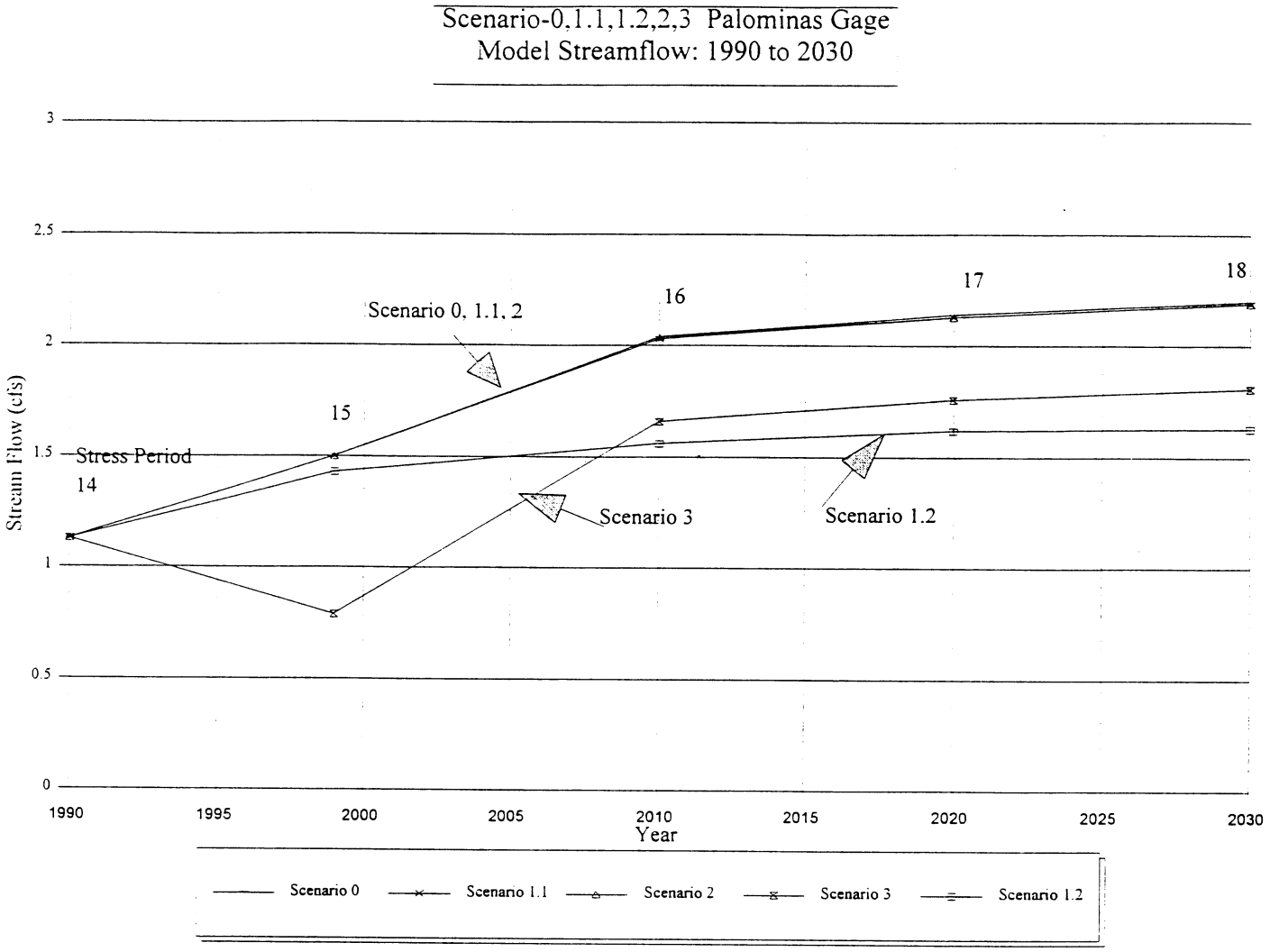
Scenario	2030 Population	2030 Pumpage (ac-ft/yr)	Effluent Recharge (ac-ft/yr)	Maximum Water Level Change (ft)				% Change in Baseflow vs. 1990		
				Sierra Vista	Palominas	Hereford	Charleston	Palominas	Charleston	Tombstone
0	51,400	9,532	0	- 45	+5	+ 10	- 5	+ 94%	+19%	- 6%
1.1	73,870	13,604	2,944	- 50	+ 5	+ 10	- 5	+ 94%	+30%	+ 2%
1.2	73,870	15,228	2,944	- 50	0	0	- 5	+ 14%	0%	- 14%
2	68,330	12,518	2,944	- 45	+ 5	+ 10	- 5	+ 94%	+ 30%	0%
3	77,724	14,153	0	- 90	+ 5	+ 10	- 5	+60%	- 5%	- 23%

References

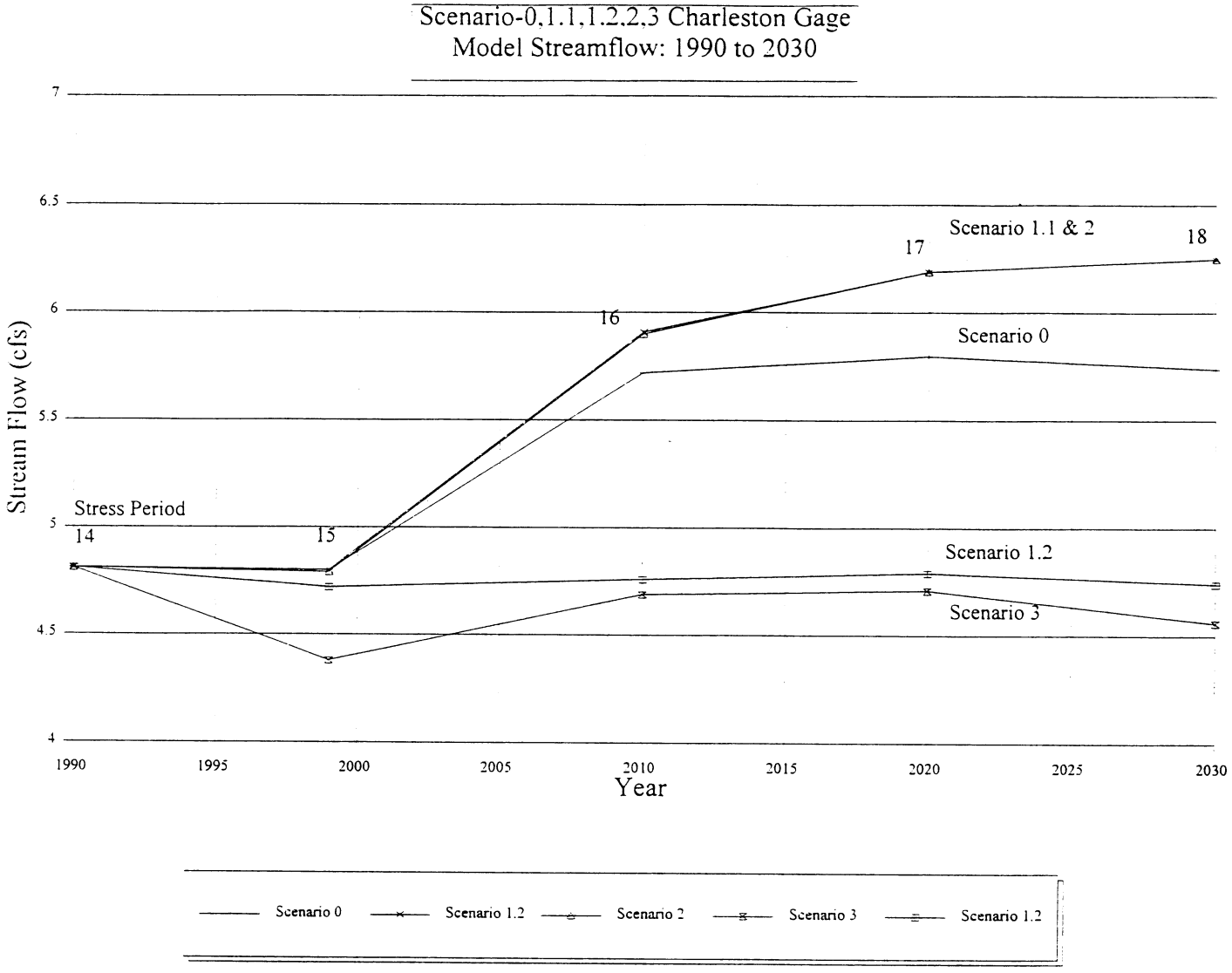
Corell, S.W., Corkhill, E.F., Lovvik, D., Putman, F., 1996; A Groundwater Flow Model of the Sierra Vista Subwatershed of the Upper San Pedro Basin-Southeastern Arizona, Arizona Department of Water Resources-Hydrology Division, Modeling Report No. 10

Appendix I

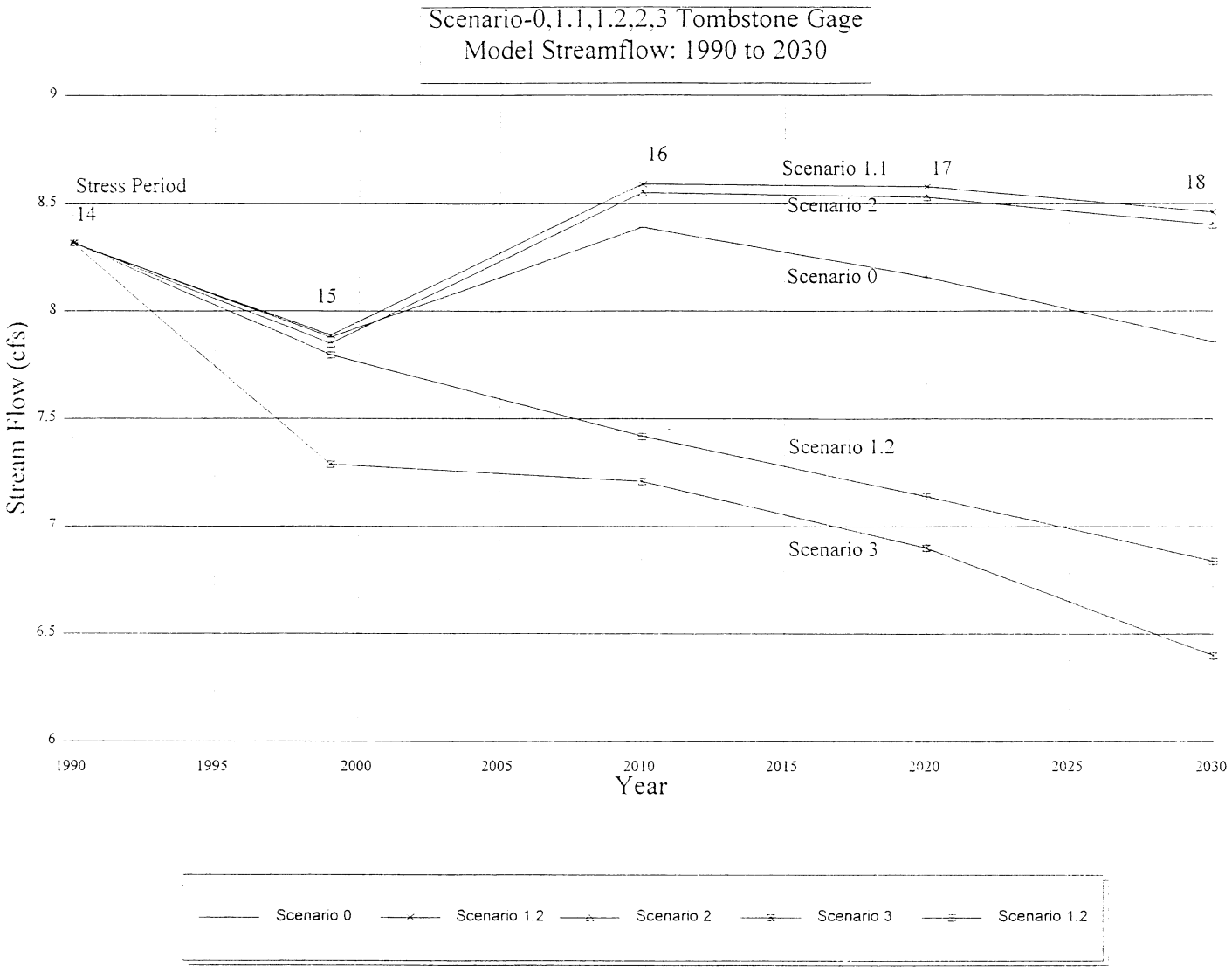
Graph 1


Scenario-0,1.1,1.2,2,3 Palominas Gage
Model Streamflow: 1990 to 2030
Stream Flow (cfs)
3
2.5
2
1.5
1
0.5
0
1990
1995
2000
2005
2010
2015
2020
2025
2030
Year
Scenario 0, 1.1, 2
Stress Period
14
15
16
17
18
Scenario 3
Scenario 1.2
Scenario 0
Scenario 1.1
Scenario 2
Scenario 3
Scenario 1.2

Graph 2


Scenario-0,1.1,1.2,2,3 Charleston Gage
Model Streamflow: 1990 to 2030
Stream Flow (cfs)
7
6.5
6
5.5
5
4.5
4
Stress Period
14
15
16
17
18
Scenario 1.1 & 2
Scenario 0
Scenario 1.2
Scenario 3
1990
1995
2000
2005
2010
2015
2020
2025
2030
Year
Scenario 0
Scenario 1.2
Scenario 2
Scenario 3
Scenario 1.2

Graph 3


Scenario-0,1.1,1.2,2,3 Tombstone Gage
Model Streamflow: 1990 to 2030
Stress Period
14
15
16
17
18
Scenario 1.1
Scenario 2
Scenario 0
Scenario 1.2
Scenario 3
Stream Flow (cfs)
9
8.5
8
7.5
7
6.5
6
1990
1995
2000
2005
2010
2015
2020
2025
2030
Year
Scenario 0
Scenario 1.2
Scenario 2
Scenario 3
Scenario 1.2